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DESIGN AND OPTIMIZATION OF AUTOMOTIVE MULTI-LEAF SPRING BY FINITE ELEMENT METHOD

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Abstract

The automobile industry has shown increased interest in the replacement of steel spring with fibre glass composite leaf spring due to high strength to weight ratio. The present study describes design and comparative analysis of multi-leaf spring made of three different materials. The modelling of the leaf spring has been done in commercially used FEM software ANSYS 14.0, and for finite element analysis the model was imported in the Static Structural analysis and Harmonic Response workbench of ANSYS 14.0. The Materials used for the multi-leaf spring is AISI 6150 Steel (Oil Quenched 845°C and 650°C tempered), Ti-6Al-4V alloy and S-Glass fiber Composite. Harmonic analysis for vibrations due to road irregularity is carried out for all the materials. von-Mises stress and deformation is the output parameters in static structural analysis..

***Keywords**:* Multi Leaf Spring, FEM, ANSYS, Static Structural Analysis, Harmonic Analysis.

1. Introduction

Leaf springs are one of the oldest suspension components that are still frequently used, especially in commercial vehicles. Leaf spring is one of the key components of vehicle suspension system. Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced materials. Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. To meet the needs of the natural resource conservation, energy and economy, recently the automobile manufacturers have been attempting to minimize the weight of the vehicle.

More efforts are taken in order to increase the comfort of the user. Appropriate balance of comfort riding qualities and economy in the manufacturing of leaf springs has become an essential requirement. Multi-Leaf springs are vital suspension elements used on mini loader trucks necessary to minimize the vertical vibrations, impacts and jolts due to road inconsistency and to ensure safety of the passengers and cargo. Many past recorded data shows that steel leaf springs are manufactured by EN45, EN45A, 60Si7, EN47, and 50CrMoCV etc. these materials are widely used for the manufacture of the conventional multi leaf springs.The introduction of the composite materials made it possible to reduce the weight of the leaf springs without any diminution of load carrying capacity and stiffness. Studies were conducted on the application of the composite materials for automobile suspension system (leaf springs).

Non-ferrous metals are also used including phosphorous and titanium for parts necessitating corrosion resistance and beryllium for springs carrying electrical current. Multi leaf springs used in the automotive vehicles normally consist of full length leaves and graduated length leaves. The specimen under this study consists of seven leaves. Finite element analysis using ANSYS 14.0 software has been carried on multi-leaf springs to obtain approximate solutions to the boundary value problems in engineering. Multi-Leaf springs were modelled in typical way and simulated for the kinematic and dynamic comparatives. In the present study, leaf spring has been analysed for static strength and harmonic response using 3D finite element analysis. ANSYS 14.0 has been utilized in the creation of the three dimensional model and its static structural and harmonic response for analysis when subjected to vertical loads.

2. Problem Formulations

Multi-Leaf Spring for commercial vehicle needs to be of high strength in order to minimize the vertical vibrations, impacts and bumps due to road irregularities and to ensure safety of the passengers and cargo. The main objective of this work is:

- To develop structural modelling of Multi-Leaf Spring using ANSYS Design 14.0 software.
- Static structural and Harmonic response analysis of Multi-Leaf Spring using ANSYS v14.0.
- Comparison between AISI 6150 Steel (Oil Quenched 845 °C and 650 °C tempered), Ti-6Al-4V alloy (Annealed) and S-Glass Fiber Composite Multi-Leaf spring in terms of deformation, von-Mises stress and Amplitude (mm) versus frequency curves.

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3. Materials for Multi-Leaf Spring

The materials which are widely used for production of the parabolic leaf springs and conventional multi leaf springs are EN45, EN45A, 60Si7, EN47, 50Cr4V2, 55SiCr7 and 50CrMoCV4 etc. The leaves are heat treated after the forming process. The heat treatment of spring steel products imparts greater strength and therefore greater load bearing capacity. In general terms higher alloy content is mandatory to ensure adequate harden ability when the thick leaf sections are used. The materials used in this work are AISI 6150 Steel, Ti-6Al-4V alloy and S-Glass Fiber Composite. Compositions of these materials are listed in table 1a-c.

Table 1a: Composition of AISI 6150 Steel used in this study

Elements	C	Cr	Fe	Mn	P	Si	S	V
%Composition	0.48%	0.8%	97.09%	0.7%	0.035%	0.15%	0.040%	0.15%

Table 1b: Composition of Ti-6Al-4V alloy used in this study

Elements	C	Fe	N	V	Al	Ti	H	O
%Composition	0.080%	0.4%	0.050%	3.5%	5.5%	87.6%	0.015%	0.20%

Table 1c: Composition of S-Glass Fiber Composite used in present study

Elements	Al_2O_3	B_2O_3	BaO	CaO	FeO	MgO	NaO_2	Other	SiO_2
%Composition	24.8%	0.01%	0.2%	0.01%	0.21%	10.27%	0.27%	0.03%	64.2%

Selected mechanical property of AISI 6150 Steel, Ti-6Al-4V alloy and S-Glass Fiber composite is discussed in table 2.

Table 2: Mechanical Property of Materials used in present study

Materials→ / Parameters↓	AISI 6150 Steel	Ti-6Al-4V alloy	S-Glass Fiber Composite
Density	7.85 g/cc	4.42 g/cc	2.48 g/cc
Young's Modulus, E	205 GPa	105GPa	86.9GPa
Poisson's Ratio	0.29	0.31	0.22
Ultimate Tensile Strength	1015 MPa	895MPa	4585MPa
Tensile strength, Yield	979 MPa	828MPa	--

4. Geometrical Parameters of Multi-Leaf Spring

Modern application of old leaf springs is the parabolic leaf spring for automobiles. The new innovative design is distinguished by the use of less leaves whose thickness varies from the centre to the outer side following a parabolic pattern. In addition to shocks, the leaf springs may carry loads, brake torque, driving torque, etc. Parabolic leaf springs for automobiles has better load bearing capacity with less weight. In the present work multi-leaf spring of commercial vehicles is considered for analysis. The modelling of the Leaf Spring has been carried out in ANSYS Design 14.0 and the geometrical parameters are shown in table 3.

Table 3: Geometrical Parameters of Multi-Leaf Spring

Parameters	**Value** (all dimensions are in mm)
Distance between eyes	1291
Thickness of all leaves	10
Width of each leaves	60
Total number of leaves	7 Leaves
Free Camber	150

The basic view of Multi-Leaf Spring is shown in Fig. 1a&b.

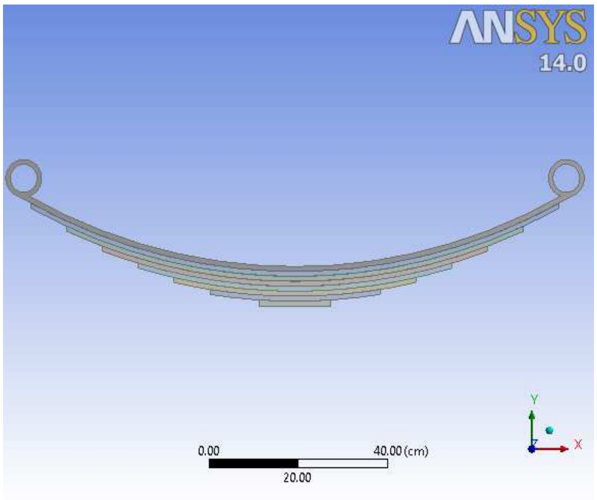

Fig.1a Front View of Multi-Leaf Spring

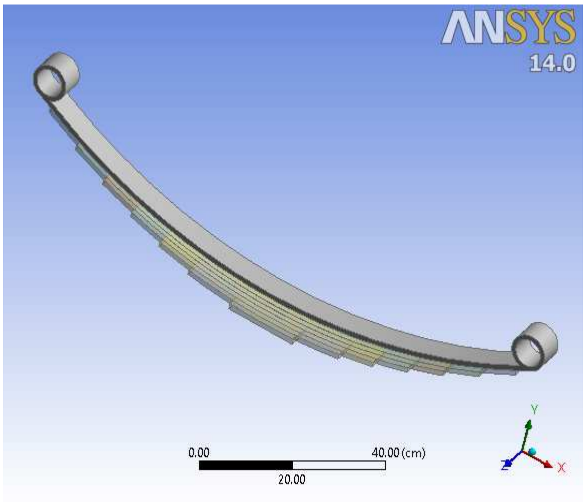

Fig. 1b Top view of Multi-Leaf Spring

5. Finite Element Analysis

The study has been carried out on a multi-leaf spring consisting of seven leaves used by commercial vehicle. Multi-leaf spring of given specification is subjected to Static structural and Harmonic response analysis using ANSYS to find the stresses and deformation. The main objective of this analysis is to study the multi-leaf steel leaf spring and verification of the results within the desirable limits. The general process FEA is divided into three phases, Pre-Processor, Solution and Post-Processor. Virtual modelling of the leaf spring is done and is imported to ANSYS 14.0 workbench. Same model is used for the static analysis as well as for harmonic response analysis with three different materials, namely AISI 6150 Steel, Ti-6Al-4V alloy and S-Glass Fibre Composite.

5.1. Meshing

Mesh Generation is one of the most critical aspects of engineering simulations. Meshing involves division of the entire model into small pieces called elements. It is also known as piecewise approximation. In present case, number and type of elements taken is shown in table 3. Meshed Surface is shown in Fig. 2.

Table 3: Total number of Nodes and Elements

Entity	Size
No. of Nodes	28861
No. of Elements	12410

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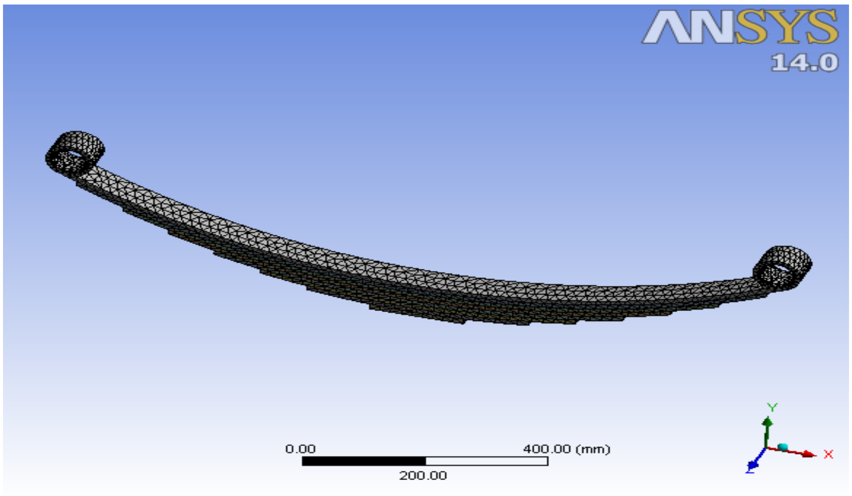


Fig.2: Meshed Surface of Multi-Leaf Spring

6. Results and Discussions

6.1. Static Analysis

Using ANSYS, Static analysis is carried out after applying the boundary conditions. The maximum von-mises stress and maximum deformation in AISI 6150 steel, Ti-6Al-4V alloy and S-Glass fibre composite is shown in Fig 4a-f. A graph is plotted as shown in Fig. 5 between Load and Von-mises stress. It is evident from the graph that there is a linear relation between load and bending stress.

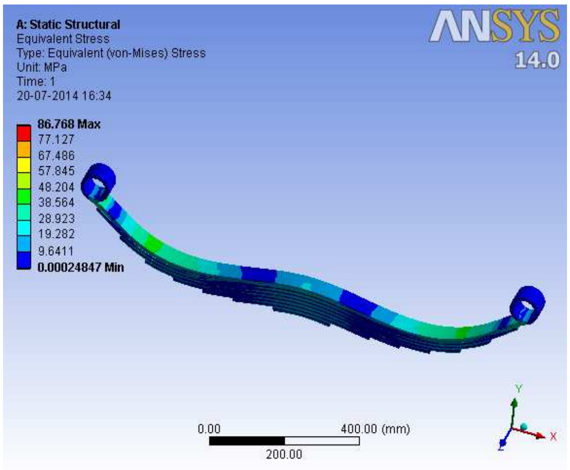
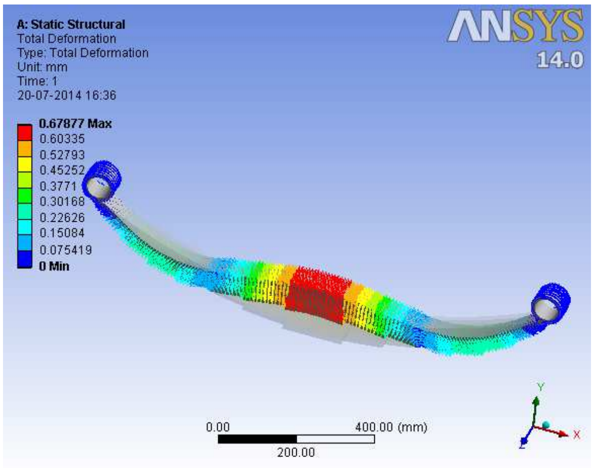
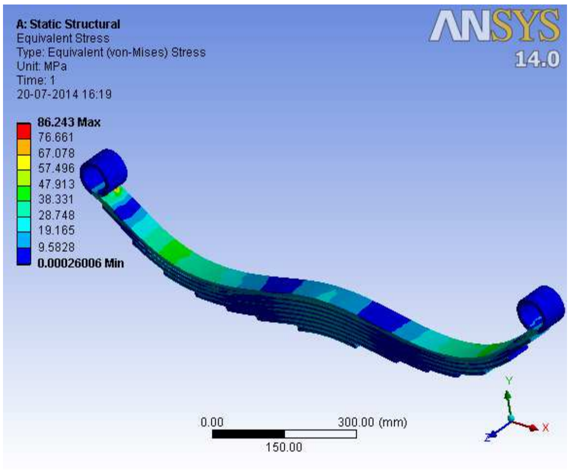


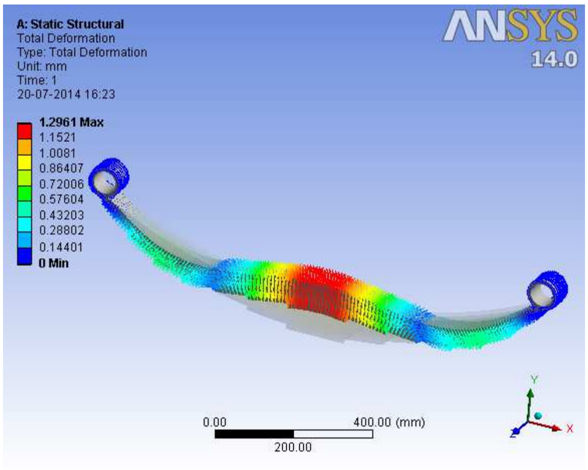
Fig. 4a: Von-Mises stress in AISI 6150 Steel



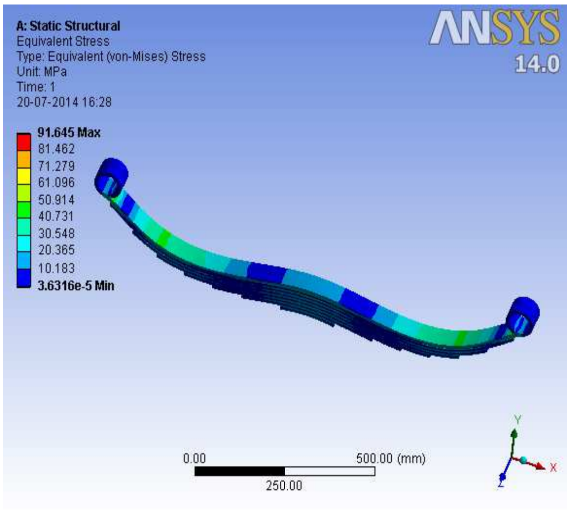
4b: Deformation in AISI 6150 Steel (Vector Display)



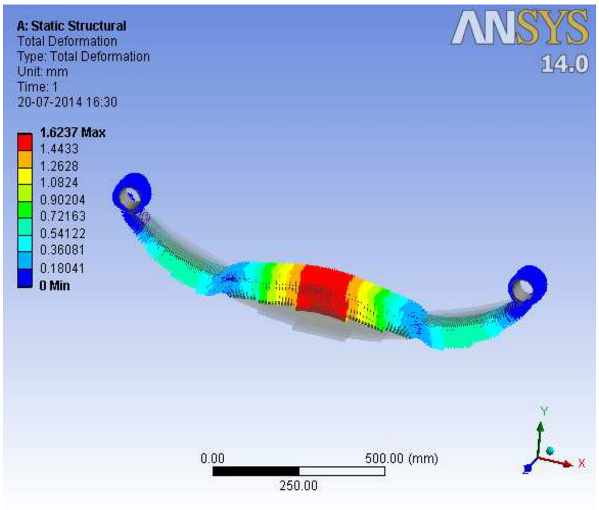
4c: Von-Mises stress in Ti-6Al-4V Alloy



4d: Deformation in Ti-6Al-4V alloy



4e: Von-Mises stress in S-Glass Fiber Composite



4f: Deformation in S-Glass Fiber Composites

Vertical load, ranging from 1000 N to 25000 N, is applied. Parameters under considerations are Maximum von-Mises Stress and weight of the multi-spring materials.

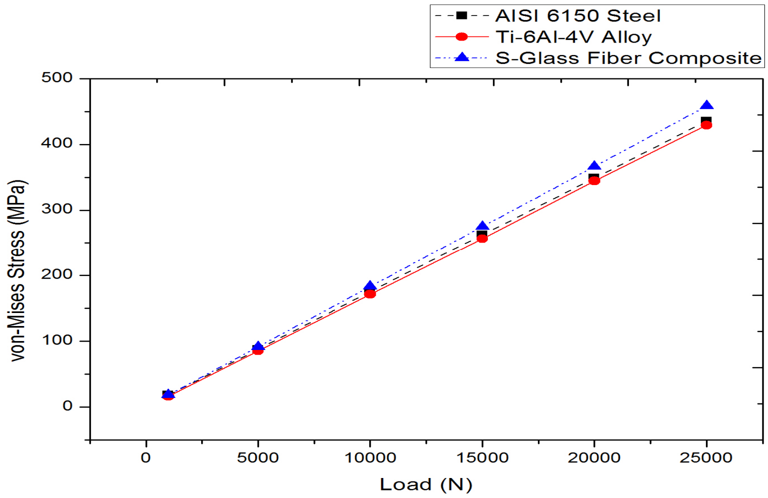


Fig. 5: Liner relationship between applied load and von-Mises stress

6.2. Harmonic Analysis

Harmonic response analysis is a technique used to determine the steady-state response of a linear structure to loads that vary harmonically with time. Main motive is to calculate the structure's response at several frequencies and obtain a graph of displacement versus frequency. Plot of amplitude versus frequency for AISI 6150 steel, Ti-6Al-4V alloy and S-Glass Fiber Composite is shown in Fig. 6a-c.

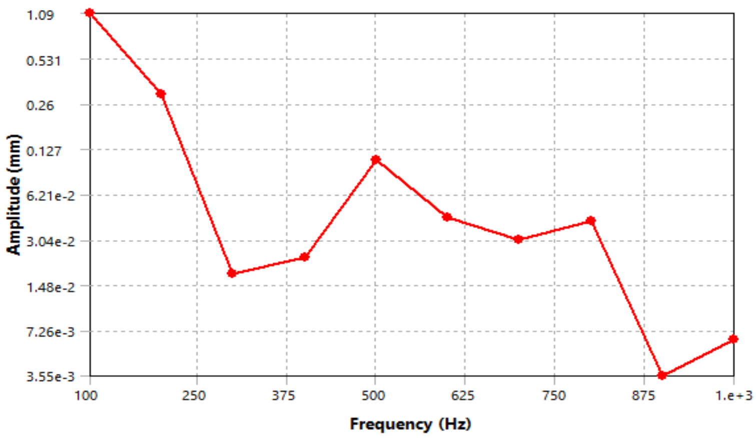


Fig. 6a: Amplitude vs. Frequency curve for AISI 6150 steel leaf spring

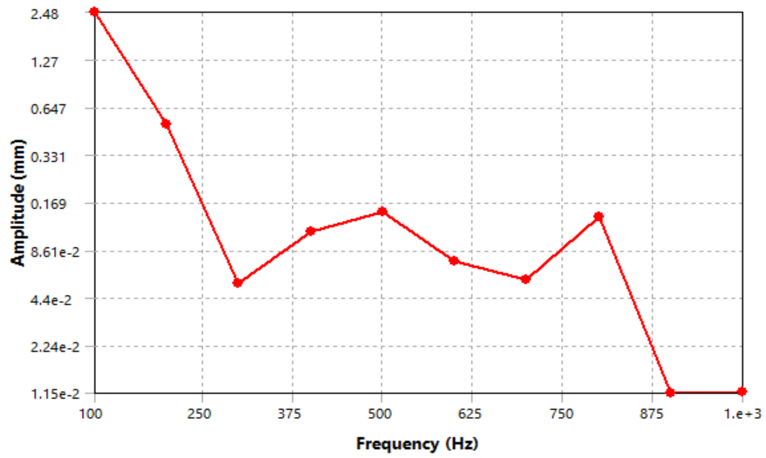


Fig. 6b: Amplitude vs. Frequency curve for Ti-6Al-4V Alloy leaf spring

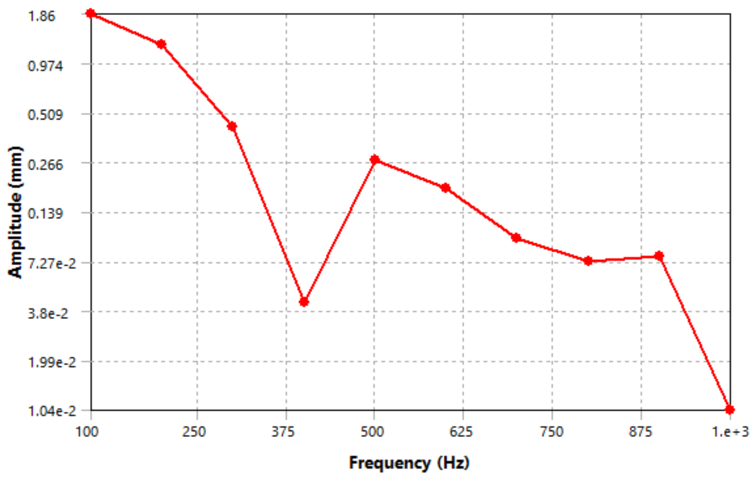


Fig. 6c: Amplitude vs. Frequency curve for S-Glass Fiber Composite leaf spring

7. Conclusion

The leaf spring based on S-Glass Fiber Composite and Ti-6Al-4Valloy has a lower mass compared to AISI 6150 Steel. Total mass of S-Glass Fiber Composite, Ti-6Al-4V alloy and AISI 6150 steel based multi-leaf spring is 10.278 Kg, 18.318 Kg and 32.532 Kg respectively. Reducing the leaf spring mass in automobiles, we can achieve better riding comfort against hard braking and acceleration. Under the same static load conditions the stresses in leaf springs are found with great difference. Stress in S-Glass Fiber Composite is found to be more as compared to conventional AISI 6150 steel. Titanium alloy based leaf spring, under same static loading conditions, shows lesser stress than S-Glass Fiber composite and AISI 6150 steel based leaf spring.

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Biography

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